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USES OF OUTER SPACE

SCIENTIFIC AND TECHNICAL PRESENTATIONS TO THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE

Report by the Secretariat

1. During the twenty-ninth session of the Scientific and Technical Subcommittee, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) and the International Astronautical Federation (IAF), in liaison with Member States, organized a symposium on the theme "Space technology and the Earth's environment". The symposium was organized in accordance with the recommendation of the Subcommittee at its twenty-eighth session, in 1991, that the theme fixed for special attention at the 1992 session be "Space technology and the protection of the Earth's environment: development of endogenous capabilities, in particular in the developing countries and in the context of International Space Year" and that COSPAR and IAF be invited to arrange a symposium on the subject (A/AC.105/483, paras. 115 (g) and 116). The recommendation was subsequently endorsed by the Committee on the Peaceful Uses of Outer Space and by the General Assembly in resolution 46/45 of 9 December 1991.

2. The symposium was the eighth to be organized by COSPAR and IAF during the annual meetings of the Scientific and Technical Subcommittee, with the topic for each year selected by the Subcommittee at the previous session. The symposium was held on 24 February 1992 as part of the special session to celebrate International Space Year (ISY). That session was organized in accordance with the recommendation of the General Assembly in resolution 46/45 that the Committee itself and its Scientific and Technical Subcommittee should dedicate at least one meeting of their regular sessions to International Space Year.

3. The special session to celebrate ISY was addressed by the Chairman of the Space Agency Forum for International Space Year (SAFISY), Mr. Hubert Curien, Minister of Research and Technology of France, and by Dr. Louis Friedman, Executive Director of the Planetary Society. The meeting also included a panel discussion on "Space and the Global Change Programme", with the

participation of senior officials of the space agencies of Brazil, France, India, Japan and the United States of America, and of the European Space Agency (ESA).

4. In addition to these special presentations organized by COSPAR and IAF at the request of the Subcommittee, delegations of Member States provided a number of scientific and technical presentations by specialists in space science and applications relating to various items on the agenda of the Subcommittee. Several international organizations also made special presentations on their scientific and technical activities.

5. The theme for International Space Year is "Mission to Planet Earth", and many of the ISY activities will be focusing on the study and monitoring of the global environment. This theme reflects the increasing concern about environmental matters and the recognition that the space community can and must react. New satellites recently launched, and those being planned and developed, will extend measurements into the microwave region of the spectrum and further develop multispectral techniques. Computer-based geographic information systems are expanding capabilities for integrating data from a variety of sources and providing information rapidly and flexibly in response to specific environmental management requirements. New ways to analyse data to study land development, atmospheric processes and ocean phenomena are being developed in many countries. Global climate change affects all countries, and the collaboration of all countries will be necessary to ensure that human activities do not seriously harm the environment.

6. The main coordinating body for global cooperation in space research during ISY is the Space Agency Forum for International Space Year, which includes 29 space agency members and 10 international affiliates, including the United Nations. SAFISY has focused attention on the advantages of coordinating national research activities so as to maximize their scientific return, especially through data analysis. By merging data from national spacecraft during ISY, scientists can create an end result comparable to what might come from an international space fleet. New cooperative procedures are being developed that recognize the importance and independence of national space agencies while seeking productive interactions among the space research community on a global basis.

7. As part of ISY activities, the European Space Agency has coordinated exchange of data from its new ERS-1 remote sensing satellite with other interested partners. It is recognized that although satellites do not in themselves constitute a solution to economic and social development needs or environmental problems, they are an excellent tool for analysing those problems. ESA intended to submit to the United Nations Conference on Environment and Development (UNCED) in Brazil a report on Earth observation by satellite.

8. A key element of the long-term European Earth observation plan is the Polar Platform, which is being developed within the framework of the ESA Columbus programme. The Polar Platform will be an expandable satellite with a

lifetime of four to five years and a modular configuration allowing a flexible multi-mission approach for payloads in the 1,000 to 2,500 kg range. Two parallel series of platforms are planned: one for observations relating to meteorology, ocean and climate; the second for observing the land surface and natural resources. While concentrating on different areas, both will make a significant contribution to the International Global Change Programme.

9. Data from the French SPOT (Satellite pour l'observation de la terre) has been used throughout the world, including in developing countries for natural resources management. A project for cartography and land use statistics in the Philippines, for example, was supported by the World Bank, and the results are being used in developing a policy for resources and environmental management. Another project was financed by the European Fund for Development and the European Economic Community (EEC) and involved monitoring renewable natural resources in the Sahel region. Remote sensing data have also proved useful in agricultural assistance projects in Morocco, Indonesia, Burkina Faso, Mali and Chad for managing irrigated areas. A project to produce a map and inventory of deforestation in South-East Asia and to train national experts in methods of monitoring tropical forests has been undertaken by France and the South-East Asian Ministers of Education Organization (SEAMEO). The countries involved are Brunei Darussalam, Indonesia, Malaysia, the Philippines and Thailand. The aim is to analyse an area of more than 3 million square kilometres over a three-year period.

10. The most important ISY event in Japan will be the Asia-Pacific ISY Conference to be held at Tokyo in November 1992. On 11 February 1992, the National Space Development Agency (NASDA) of Japan launched the Japanese Earth Resources Satellite-1 (JERS-1) with L-band synthetic aperture radar, which should be particularly valuable for ocean and ice observations. NASDA is currently developing the Advanced Earth Observing Satellite (ADEOS), which is scheduled for launch in 1995, and is planning the Tropical Rainfall Measuring Mission (TRMM) in cooperation with the United States National Aeronautics and Space Administration (NASA). Japan established the Japanese ISY Association last year to promote ISY events planned by many Japanese organizations. Japan has also been co-leading two SAFISY earth science and technology projects: the Sea Surface Temperature Project, and the Polar Ice Extent Project. At the Asia-Pacific conference, the use of space remote sensing data to predict global change will be demonstrated.

11. The United States Global Change Research Program will focus in the near term on the scientific uncertainties in global change assessments as well as on the research needs identified by the International Geosphere-Biosphere Programme (IGBP) and the world climate research programme (WCRP). The United States programme seeks to address the implications of environmental changes, working through domestic and international forums such as the Intergovernmental Panel on Climate Change (IPCC), the Montreal Protocol, the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change, the United Nations Conference on Environment and Development and other important but lesser known activities.

12. NASA's Mission to Planet Earth activities, a key part of the United States Global Change Research Program, is focused primarily on space-based studies of the Earth as an integrated system. This programme builds upon past NASA satellite missions which have used a variety of remote sensing instruments to study components of the Earth system. During the first phase of NASA's Mission to Planet Earth, which is already under way, the United States and its international partners will launch 16 free-flying satellites to make global change observations. In addition, three major Spacelab missions will be launched on the Space Shuttle to study global change.

13. Preliminary results from the first spacecraft, the Upper Atmosphere Research Satellite (UARS), which was successfully deployed from the Space Shuttle Discovery in September 1991, include global ozone maps, detailed observations of the Antarctic ozone hole and the first global-scale measurements from space of chlorine monoxide. A large plume of sulphur dioxide from the eruption of Mount Pinatubo in the Philippines was detected and mapped globally, and observations were made of ozone concentrations within the plume. An intensive programme is under way to analyse the UARS data and correlate it with a broad programme of ground-, balloon-, aircraft- and rocket-based experiments and measurements.

14. Two other NASA Mission to Planet Earth activities were undertaken in 1991. In August, a Tsiklon rocket was launched from the Russian Plesetsk cosmodrome, carrying a Meteor-3 spacecraft with a United States Total Ozone Mapping Spectrometer (TOMS) on board. This instrument serves as a complement to the TOMS instrument on board the Nimbus-7 satellite. Earlier in the same month, the Shuttle Solar Backscatter Ultraviolet instrument was flown on the Space Shuttle Atlantis, providing space-based measurements of the total ozone and its vertical distribution.

15. Studies to be undertaken by India during ISY will cover changes in monsoon patterns, snow-melt variations, study of cloud radiation, greenhouse warming, monitoring of forest cover, marine pollution and mapping of flooded and flood-prone areas. Monitoring techniques have resulted in improvements in controlling deforestation and urban sprawl, as well as in monitoring monsoon-related phenomena. India has acquired a vast amount of data through balloon-, rocket- and ground-based observations, as well as through satellite remote sensing. Other activities planned in India for ISY include mobile space exhibitions to generate public awareness of global change phenomena, in-depth workshops on ongoing projects and training courses on satellite data interpretation and its use in monitoring global change.

16. The Chinese Meteorological Satellite FengYun-1, as well as NOAA and GMS satellite images have been used for natural disaster monitoring and protection, including observations of the 1991 floods in eastern China, and the 1987 forest fires in northeastern China. Satellite images are also used in China for other applications, including greenness monitoring for agriculture, snow cover monitoring for water resources in western China, sea ice monitoring for navigation and petroleum drilling in offshore areas, sea-surface temperature monitoring for fishing and sand and mud distribution monitoring for port construction feasibility studies.

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17. ERS-1, the European Space Agency's first remote sensing satellite, was successfully placed in orbit by an Ariane launcher on 16 July 1991. Within a few weeks after launch, it was confirmed that the ERS-1 Synthetic Aperture Radar (SAR) can be used to study ocean, ice and land features, similar to those seen with the Seasat radar which operated in 1978 at a different frequency and polarization. ERS-1 is providing global data sets comprising measurements of sea conditions such as wind, waves and surface temperature.

18. Estimates of the deforestation rate in the Brazilian Amazon region over the last few years have varied by a factor of four. These estimates are important for understanding the global greenhouse effect, to which tropical deforestation makes a significant contribution. Recent Landsat-based estimates undertaken in Brazil seem to represent the most reliable values to date for Amazonian forest-clearing. To continue, expand and improve these studies, a World Forest Watch (WFW) is being prepared in conjunction with International Space Year. The project is coordinated by the Brazilian Institute for Space Research (INPE) and the Joint Research Centre of the European Commission. The project strategy includes a global forest monitoring component, using Advanced Very High Resolution Radiometer (AVHRR) data from NOAA satellites, and a regional forest monitoring component using Landsat and French SPOT data. The global component covers West and Central Africa, South America and South and South-East Asia. The Amazonian regional component covers parts of Bolivia, Brazil, Colombia, Peru and Venezuela. The first results of the WFW project are to be presented in May 1992 during the World Forest Watch Conference in Brazil.

19. The United States National Operational Hydrologic Remote Sensing Center creates and distributes a variety of products that use remote sensing data in support of the hydrologic services of the National Weather Service (NWS). The most widely used Center products are estimates of snow cover based on satellite and aircraft data. The Center operates two gamma-ray sensors on low-flying aircraft to measure snow water equivalent over an area including portions of 25 states and Canadian provinces. Additionally, analysts use AVHRR data on the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites and from the Geostationary Operational Environmental Satellite (GOES) to produce digital maps of the area of snow cover for over 4,000 river basins in the United States (including Alaska) and in Canada. All of the hydrological information derived from remote sensing is being integrated into NWS plans for an enhanced Water Resources Forecasting System.

20. For the Indian Space Research Organization (ISRO), a major priority is the use of space technology to promote sustainable development of natural resources. Sustainable development in developing countries must be based on maintaining the fragile balance between production requirements and conservation practices through the monitoring and identification of problem areas that require alternate agricultural practices, crop rotation, use of bio-fertilizers, energy-efficient farming methods and reclamation of unused lands. The adoption of ecologically sound technologies, including integrated pest management, nutrient supply and soil and water conservation, will require the cooperation of rural farming families in managing the land and water

resources on their smallholdings. Many conservation projects attempted so far have failed because they have only addressed symptoms and not causes of land degradation. New land use practices have often been imposed from the top without concern for cultural sensitivity and the total involvement of local communities.

21. To promote sustainable development, ISRO is working on a new educational programme using audio-visual media disseminated via a dedicated satellite system called GRAMSAT, which will be tailored to meet the specific requirements of rural areas for culture- and region-specific knowledge relating to health, hygiene, family planning, improved agricultural practices and environmental protection in each of the regional languages of India. The GRAMSAT satellite will carry six to eight 6/4 gigahertz transponders to distribute television programming for local rebroadcast and reception on ordinary television sets in each house or village. Through the use of video compression techniques, the satellite capacity can be increased to provide coverage of over 90 per cent of the national population. Two or three additional high-power spot-beam 14/11 gigahertz transponders will allow direct reception through antennas as small as 0.8 metres in diameter and will be used particularly for continuing education for industrial workers in urban areas. The system will be developed during the coming five to six years.

22. The Global Change Encyclopedia is an educational programme being developed in Canada for 1992 in the context of International Space Year and the Global Change Programme. It is a computer-based environmental information system designed particularly for use in schools. The Encyclopedia will consist of a variety of global environmental data distributed on CD-ROMs (compact disk - read-only memory) together with computer programs for examining and manipulating the data on a personal computer. The system will function like a simple environmental geographic information system, allowing selection of a geographic area, display of images, overlay of different data and enlargement and enhancement of areas and features of interest.

23. For the NASA Life Sciences Program, the past year has been very rewarding. The Spacelab Life Sciences-1 (SLS-1) mission, which flew in June 1991, was the first Space Shuttle mission dedicated entirely to space life sciences. Investigators from Australia, Canada, France, Germany, the Russian Federation, Switzerland and the United States conducted flight experiments. The results of SLS-1 have provided new insights into human adaptability to extreme environments and will provide a better understanding of the health parameters that need to be monitored during human space flight.

24. Another Space Shuttle mission of major importance was the International Microgravity Laboratory-1 (IML-1) mission, which flew in January 1992. Thirteen countries contributed experiments to the mission, which featured an international crew of astronauts from Canada, Germany (representing ESA) and the United States. The mission was devoted to life sciences and material sciences, with the primary objective of studying the effects of microgravity on living organisms and materials processes. The life sciences investigations addressed a variety of topics in human physiology, human performance and the space radiation environment.

25. Most telecommunication satellites today use the geostationary orbit, but the increasing congestion of the orbit makes it desirable to consider alternative orbits. The main attraction of the geostationary orbit is that, seen from the ground, a satellite always appears at the same position in the sky. Hence the ground stations do not have to track a rapidly moving satellite, and a single satellite can provide continuous links between all ground stations within its "footprint" covering about one third of the Earth's surface. As an alternative to the geostationary orbit, highly elliptical inclined orbits have been used by Russian Molniya communication satellites since 1965. For ground stations located at high latitudes, a system consisting of three such satellites with on orbital inclination of 63.43° and an orbital period of either 12 or 24 hours offers the advantage that the satellites are much higher over the local horizon. A disadvantage of a system of two or more satellites in inclined elliptical orbits is the need for the ground stations to switch from one satellite to another several times a day. Orbits therefore need to be carefully selected and maintained to allow optimal switching between satellites and to ensure uninterrupted service.

26. The growing population of man-made space debris has become the subject of increasing concern in recent years, and a number of countries are studying the question. Collision-avoidance manoeuvres had already been performed during two Space Shuttle missions. While the concentration of debris is highest in low orbits, debris can also present problems in the geostationary orbit. Active geostationary satellites are normally maintained within 0.1° of their nominal longitudes. In some cases the same longitude is assigned to more than one satellite, in which case it is up to the satellite operators to coordinate their station-keeping manoeuvres so as to avoid collisions. There is currently no general rule for collision-avoidance procedures. For a theoretical sample of 100 active and 100 inactive objects in and near the geostationary orbit, it was calculated that one collision would occur in 500 years in the absence of collision-avoidance measures. However, at the distance of the geostationary orbit, objects smaller than 1 metre in diameter are presently non-trackable, and therefore their precise number is unknown. According to some investigators, debris generated in the geostationary orbit stay close to the orbit and spread within weeks to all longitudes. The relative speed of objects in and near the geostationary orbit is typically that of two jet planes colliding head-on, and collisions therefore generate very large numbers of small fragments. Since debris generated in such collisions stays permanently near the geostationary orbit, it could lead to a chain reaction series of collisions.

27. NASA has embarked on an extensive programme to study the universe across the entire electromagnetic spectrum. The purpose of this programme in space astronomy and astrophysics is to further human knowledge about the universe in which we live. The core of the NASA programme is the Great Observatory projects, designed to provide observations in various regions of the electromagnetic spectrum with unprecedented sensitivity and angular and spectral resolution. Complementing the Great Observatories is the Explorer programme, consisting of moderate and small-scale missions. Two recent successes in this programme are the ROSAT mission, a cooperative effort with

Germany and the Cosmic Background Explorer (COBE). COBE has already provided data offering strong confirmation of the Big Bang theory. Exciting new results have also been obtained for Venus by the Magellan mission and for the small asteroid Gaspra by the Galileo mission, which is continuing on its trajectory to Jupiter.

28. Since space astronomical investigations are of great interest to the public, NASA has recently started a new Initiative to Develop Education through Astronomy (IDAE) to promote education at every level using the excitement of astronomy as a motivational and pedagogical tool. For International Space Year, the project "Mission to the Universe" has been initiated to share the adventure of astronomical discovery with all of the people of the world. It is hoped that the example of international and cross-cultural cooperation that has made possible the achievements of space astronomy can be an inspiration to nations seeking a peaceful road to a secure and prosperous future.

29. The annex to the present report contains a more detailed summary of the scientific and technical presentations during the session of the Scientific and Technical Subcommittee. Because of the technical character of the material, the annex is given in English only. A list of the presentations and the speakers is contained in the appendix to the annex.

Annex

SUMMARY OF SCIENTIFIC AND TECHNICAL PRESENTATIONS IN THE SCIENTIFIC AND TECHNICAL SUBCOMMITTEE

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I. SPECIAL SESSION TO CELEBRATE INTERNATIONAL SPACE YEAR

A. International cooperation in International Space Year

The theme that has been chosen for International Space Year (ISY) is "Mission to Planet Earth", and many of the ISY activities will be focusing on the study and monitoring of the global environment. The importance of space technology and of international cooperation in the study of the global environment can hardly be overemphasized. The variations in the global climate are so complex that long-term, consistent, global coverage by satellite is an essential element of efforts to understand our environment. Satellite images provide irrefutable evidence of the productivity of our planet and of humankind's technological power to increase or destroy that productivity. New satellites recently launched, and those being planned and developed, will extend measurements into the microwave region of the spectrum and further develop multispectral techniques. Computer-based geographic information systems are expanding capabilities for integrating data from a variety of sources and providing information rapidly and flexibly in response to specific environmental management requirements. New ways to analyze data to study land development, atmospheric processes and ocean phenomena are being developed in many countries.

While the development of advanced space technology on the basis of cooperation between many countries has been most impressive, many countries have not been able to take advantage of these new capabilities. Scientists and managers in developing countries have faced a variety of obstacles, including a lack of education and training opportunities, difficulty in communicating with the international scientific community and obtaining current literature, and problems in obtaining and maintaining equipment. While the broadest possible international cooperation is beneficial in all areas of space activities, it is essential for monitoring the global environment. While satellites provide unique information, other sources of information including air and ground surveys are also needed if the satellite data is to be correctly interpreted. Global climate change affects all countries, and the collaboration of all countries will be necessary if we are to ensure that human activities do not seriously harm the environment.

For these reasons, the activities of the United Nations for ISY are focusing particularly on promoting the participation of developing countries in space activities. Within the very limited resources available for this purpose, the Office for Outer Space Affairs and its Programme on Space Applications, working under the direction of the Scientific and Technical Subcommittee and the Committee on the Peaceful Uses of Outer Space, are focusing on education, training and information for developing countries. These activities are possible only through the generous financial and technical support of host countries and international and national space organizations.

The ISY has a distinctive character, which combines scientific research with public involvement and education. The unifying idea is that space is both a place and a new global perspective that draws inspiration from the universal language and global outlook of Earth and space science. As the year begins, hundreds of ISY-dedicated activities are moving forward worldwide in two broad categories - scientific research and public education.

The ISY marks the emergence of national space agencies and similar international bodies as central coordinators for global cooperation in space research. The coordinating agent for that historic development is the Space Agency Forum on ISY, or SAFISY, which includes 29 space agency members and 10 international affiliates, including the United Nations. Never before have so many space agencies organized for cooperation in a global framework.

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SAFISY has focused attention on the advantages of coordinating complementary national research activities so as to maximize their scientific return, especially through data analysis. By merging data from independently operated national spacecraft during ISY, scientists can create an end result comparable to what might come from an international space fleet. At the same time, they help construct the most pragmatic foundation for long-term cooperative space research based on global research requirements. One recent example of the use of new space technology was the France-United States project TOPEX-Poseidon (Ocean Topography Experiment), which is to be launched in 1992 and will provide observations of the ocean using complex instrumentation including a highly precise altimeter. The observations will support interpretation of data from the already-launched European ERS-1 (European Remote Sensing Satellite) and JERS-1 (Japanese Earth Resource Satellite) spacecraft.

SAFISY's role in coordinating space activities has been more inspirational than managerial. It has started those involved in space research activities thinking in a broader and more comprehensive framework that is also more pragmatic. New cooperative procedures must be developed that recognize the primacy and independence of national space agencies while seeking productive interactions with the space research community on a global basis. Whether SAFISY continues beyond ISY in some other form or not, its contribution will continue to influence the character and organization of space research.

The ISY introduces a new global era in space activities. In the past, motivations for developing space activities had not always been altruistic. There were aspects of the cold war that prompted rapid, large-scale development of space resources that might not otherwise have been available. Under new conditions, the space community should seek new motivations to further promote space science and technology. Among the main reasons for the continuation and expansion of humankind's space activities is the search for fundamental laws governing our universe and our lives in it, monitoring of the environment, and of course the practical applications of space technology such as telecommunications, meteorology and remote sensing, and the spin-offs influencing all branches of daily life. The continuing role of space in education is enormous, and space has, in many countries, become a symbol and motivation of high achievement.

B. European Space Agency contributions to ISY

The European Space Agency (ESA) now has 13 members and two associated States, and its Council recently approved its long-term goals for the period 1992-2005. As part of ISY activities, ESA has coordinated exchange of data from its new remote sensing satellite ERS-1 with other interested partners. Global Earth observations from ERS-1 and other remote sensing satellites, while not in themselves a solution to problems of economic and social development or environmental protection, aret an excellent tool for analyzing those problems. In order to promote an awareness of those capabilities, ESA intends to submit to the United Nations Conference on Environment and Development in Brazil a document on Earth observation by satellites. An important new user of space monitoring services will be the European Economic Community (EEC), which recently created a European Environment Agency.

The launch of ERS-1 also marks the beginning of a new era for European Earth observation and environmental activities. It will be followed by the launch of ERS-2 in 1994 and of the first of the Polar Platform missions in 1997/1998, with the objective of providing continuity of data. In recent years, concerns about environmental matters have emerged as a major issue to which the space community can and must react. In order to meet these challenges, and in particular those of climate change, ozone depletion, deforestation and desertification, ESA has prepared an ambitious programme for Earth observation from space, building on Europe's experience with the Meteosat, Earthnet and ERS

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programmes. That programme will lead not only to better monitoring of environmental change on the global, regional and local scales, but also to a better understanding of the scientific processes that determine the environment and its variability.

A key element of the long-term European Earth observation plan is the Polar Platform, which is being developed within the framework of the Columbus programme. The Polar Platform is designed for a four to five year lifetime and will have a modular configuration allowing a flexible multi-mission approach for payloads in the 1000 to 2500 kg range. Two series of parallel missions are planned, each focusing on a different set of applications: one series will carry sensors for meteorological, oceanographic and climatic studies; the second will observe surface characteristics of the Earth and Earth resources. Both series should make significant contributions to the International Global Change Programme.

Considering the global dimensions of environmental change, international cooperation is a key factor in the realization of the initiatives undertaken by the states interested in space research. The ISY represents an important initiative in this respect, and ESA in concert with its partner organizations is taking an active part in ISY. The European Polar Platform, to be launched before the turn of the century, should be seen in this context alongside the Earth Observing System (EOS) of the United States and the Japanese space platforms. The objective is that each of these missions will provide complementary data sets to contribute to the study and assessment of the global environment.

ESA's objective is to prepare a coherent programme of Earth observations from space and to take the lead in research and development in support of future missions. This should include the conception, development and demonstration of new techniques that in the future would replace existing instruments. The operational handling of the vast amount of data produced by ESA spacecraft would be progressively handed over to other entities that are more suited to operational applications. In meteorology, this approach has lead to the creation of Eumetsat which is responsible for running the Meteosat Operational Programme. It is hoped that the European Environmental Agency will develop to take on a similar role in the area of environmental monitoring.

To promote educational activities in the context of ISY, ESA is working with the United Nations to develop pilot remote sensing projects in the African countries within the coverage zone of the receiving stations in Maspalomas, Grand Canary, Spain, and Fucino, Italy. Pilot projects from Guinea-Conakry, Morocco, Nigeria and Tunisia have been selected. ESA intends to organize training for experts who will work on these pilot projects and will assist them in using the data, beginning at the end of 1992.

C. French participation in global environmental programmes

The French SPOT (Satellite pour l'observation de la terre) satellite system is a valuable tool enabling detailed, uniform and accurate information to be gathered anywhere in the world every three to five days. SPOT is one element in the policy of cooperation between France and developing countries in the area of natural resource management. Since SPOT data are distributed commercially, this cooperation can benefit from financial support of sponsors. This was the case in a project for cartography and land use statistics in the Philippines supported by the World Bank, the results of which are being used for developing a policy for Earth resources and environmental management. Another example was the financing by the European Development Fund and the EEC of a project for monitoring renewable natural resources in the Sahel region. Remote sensing data have also proved useful in agricultural assistance projects and managing irrigated areas in Morocco, Indonesia, Burkina Faso, Mali and Chad.

The comprehensive coverage from the SPOT satellite enabled a precise evaluation of forested area and forest composition in terms of species, age and density. Applications are now under way of the study of soil deterioration through erosion. SPOT data can be used to map the global extent of erosion damage over broad areas and to formulate global indices of deterioration.

As part of the International Geosphere-Biosphere Programme (IGBP), France recently created a network for regional climate research, to be located in Toulouse and to cover the entire Mediterranean basin and subtropical Africa. The network will improve three-dimensional climate modelling to forecast local effects of global climate change, develop climate databases, and undertake education and training activities.

A joint project, aimed at producing a general cartographic inventory of deforestation in Southeast Asia and at training national experts in monitoring tropical forest, has been undertaken by France and the South-East Asian Ministers of Education Organization (SEAMEO). The countries involved are Brunei, Indonesia, Malaysia, the Philippines and Thailand. The project, which got underway in 1989, is to study an area of more than 3 million square kilometers over a three-year period. Under the terms of a contract awarded by the French Ministry of Foreign Affairs, the Scot Conseil company was chosen to organize the project and coordinate French technical assistance. The aims of the project are:

(a) To develop techniques for rapid assessment of deforestation in Southeast Asia; and

(b) To transfer to the SEAMEO Member States the expertise required to monitor deforestation by training technical experts and local users.

Forest observation in the SEAMEO member countries involves compiling a 1:2,000,000 scale map to reflect trends in forest cover over the past decade. The systematic use of remote sensing tools is the only reasonable way to attempt to cover a zone this size within the allotted time. Global studies, identifying the principal types of vegetation, are being performed using the high-frequency, low-resolution multispectral coverage provided by NOAA/AVHRR (Advanced Very High Resolution Radiometer) images. These data are supplemented by high-resolution SPOT images (10-20 m resolution as compared to 1 km for NOAA satellites), so that NOAA/AVHRR data can be "calibrated by theme." Preliminary results show that forest cover has diminished by some 25 per cent during the period observed. The final results are to be published as maps and presented to the international research community, forestry experts and decision makers at a seminar to be held in 1992 in connection with ISY.

The associated "detailed studies," undertaken in Brunei, Indonesia, Malaysia and the Philippines by teams of national foresters using SPOT images, are compiling accurate forest maps at a scale of 1:100,000 or 1:50,000 as well as statistical tables for analyzing deforested areas and identifying the consequences of deforestation. The responsibility for training the national experts and staff who will carry out the projects is assigned to the two regional scientific centers, BIOTROP (Regional Centre for Tropical Biology) at Bogor, Indonesia, and the Asian Institute of Technology in Bangkok.

D. ISY activities in Japan

The most important ISY event in Japan will be the Asia-Pacific ISY Conference to be held in Tokyo in November 1992. The main theme of this Conference is "Mission to Planet Earth". The Conference will consider the use of satellite data for studying the deterioration of the global environment and analyzing such problems as global warming, abnormal climate patterns, ozone layer depletion, and tropical forest destruction. While satellites have already provided important information, such as the

observations of the ozone hole over Antarctica by the Total Ozone Mapping Spectrometer (TOMS) aboard NASA's Nimbus-7 satellite, too many predictive factors still remain undetermined.

The difficulty of understanding global change can be illustrated with the example of global warming. The report of the Intergovernmental Panel on Climate Change (IPCC) estimated that the global temperature, averaged over time and space, will increase 0.3°C to 0.8°C over the next 10 years. It has been estimated that the average temperature in the last Ice Age was about 1°C lower than the temperature today. It is now and will continue to be impossible to directly detect this global temperature change using satellite remote sensing. From the analyses of space data, however, several important findings have been acquired. It has been found that solar irradiation fluctuates by several per cent; that clouds not only cool the Earth but, in some cases, warm it; and that the El-Niño is a part of a large sea-surface temperature anomaly in the Pacific Ocean.

Based on these findings and mathematical "global circulation model" simulations, Earth scientists now believe that there are many factors, cycles and processes which affect global warming: the greenhouse effect, trace gases, the carbon cycle, the hydrological cycle, atmosphere-ocean interactions, deforestation, and others. It is clear that global change is a complex phenomenon involving an intricate system, the planet Earth, and that much more data on fundamental processes is required, including data acquired by satellite remote sensing as well as ground observations.

Since 1972, the National Space Development Agency of Japan (NASDA) has launched and has been operating a series of Geostationary Meteorological Satellites (GMS-1, 2, 3 and 4) and two Marine Observation Satellites (MOS-1A and 1B). On 11 February 1992, NASDA launched the Japanese Earth Resources Satellite (JERS-1) with an L-band synthetic aperture radar from which new findings about ocean and ice processes can be anticipated. NASDA is now developing the Advanced Earth Observing Satellite (ADEOS), which is scheduled for launch in 1995, and is also planning the Tropical Rainfall Measuring Mission (TRMM) in cooperation with NASA.

Japan has established the Japanese ISY Association in 1991 to promote various ISY events planned by many national organizations. Japan has also been co-leading two SAFISY Earth Science and Technology projects: the Sea Surface Temperature Project and the Polar Ice Extent Project. At the Asia-Pacific ISY Conference, the use of space remote sensing data for predicting global change will be demonstrated. In the Asia-Pacific region, the deterioration of tropical forests is the major issue concerning the regional environment. Deforestation in this region induces flooding, soil deterioration and landslides. Discussions at the Asia-Pacific ISY Conference will consider concepts for regional cooperation in applying space remote sensing technology for forest monitoring, disaster prevention, and other regional environmental issues.

In the field of education, students at the Conference will be encouraged to discuss new space exploration projects for the 21st century, such as missions to the Moon and Mars. Japan is now planning the "ISY Memorial/Engineering Test Satellite (ETS-V) Pan Pacific Communication" project as part of the SAFISY Education and Application Programme. This will be a pilot project to test space communications for education and application in developing countries in the Asia-Pacific region.

Japan is also planning an ISY seminar on the "Tropical Eco-System" to be held in Thailand in June 1992 as part of the SAFISY Education and Application project "Vegetation Resources: Monitoring and Management." In addition, in September 1992, the first Japanese Payload Specialist will conduct space experiments on the United States Space Shuttle during the First Material Processing Test (FMPT). At the

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Asia-Pacific ISY Conference, preliminary results of the FMPT microgravity experiments, including 22 experiments in material science and 12 experiments in life sciences, are to be reported.

In February 1993, NASDA is planning to hold the Polar Ice Extent Workshop in Hokkaido, in northern Japan. It is expected that Japanese and European scientists will demonstrate how ice motion in the northern hemisphere can be monitored from two space-borne synthetic aperture radars: one on the European Remote Sensing Satellite (ERS-1) and the other on NASDA's JERS-1.

E. NASA participation in the Global Change Programme

The United States Global Change Research Programme is a presidential initiative for an accelerated, focused research strategy designed to reduce key scientific uncertainties and to develop more reliable scientific predictions upon which sound national and international policies and responses to global change can be based. President Bush has requested $1.37 billion for this program in fiscal year 1993. This represents an increase of 24 per cent over the 1992 level. The United States Global Change Research Programme in the near-term will focus on the scientific uncertainties identified in the assessment of the Intergovernmental Panel on Climate Change (IPCC) as well as the research needs identified by the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP). The programme seeks to address the implications of environmental change, through both domestic and international forums such as the IPCC, the Montreal Protocol, the International Negotiating Committee for a Framework Convention on Climate Change, the United Nations Conference on Environment and Development, and other important but lesser known activities.

The United States Global Change Research Programme is designed to produce a predictive understanding of the Earth system to support national and international policy-making activities that cover a broad spectrum of global and regional environmental issues. To fulfill this goal, the programme addresses three parallel but interconnected streams of activity:

(a) Documenting global change through an integrated, comprehensive, long-term programme of observation and analysis;

(b) Enhancing understanding of key processes through a program of focused studies; and

(c) Predicting global and regional environmental change through the development and application of integrated conceptual and predictive Earth system models.

NASA's Mission to Planet Earth, a key part of the United States Global Change Research Programme, is focused primarily on space-based studies of the Earth as an integrated system. This programme builds upon past NASA satellite missions which have used a variety of remote sensing instruments to study components of the Earth system. For example, instruments on board the Nimbus-7 spacecraft provided observations of marine biological productivity, and provided over a decade of data on global ozone levels, helping to identify the Antarctic ozone hole. The Seasat satellite returned the first global radar data on ocean processes, and the Earth Radiation Budget Experiment (ERBE), consisting of three satellites, has been the primary source of data for studying the Earth's radiation balance.

The first phase of NASA's Mission to Planet Earth is already underway. During this phase, the United States and its international partners will launch 16 free-flying satellites to make global change observations. In addition, three major Spacelab missions will be launched on the Space Shuttle to study global change. Preliminary results from the first of the phase one spacecraft, the Upper Atmosphere

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Research Satellite (UARS), which was successfully deployed from the Space Shuttle Discovery in September 1991, indicate that the spacecraft is a powerful new tool for studying ozone in the upper atmosphere and the processes which control it. UARS has already produced global maps which record details of the Antarctic ozone hole and made the first global measurements from space of chlorine monoxide, which plays a key role in the catalytic destruction of ozone. UARS also observed the large sulfur dioxide plume from the eruption of Mount Pinatubo, mapped the global diffusion of the plume, and measured ozone concentrations within the plume. An intensive programme is underway to analyze the UARS data and correlate it with a an extensive programme of ground, balloon, aircraft, and rocket-based measurements.

Two other NASA Mission to Planet Earth activities were undertaken in 1991. In August, a Tsiklon rocket was launched from the Russian Plesetsk cosmodrome, carrying a Meteor-3 spacecraft with a United States Total Ozone Mapping Spectrometer (TOMS) instrument on board. This instrument serves as a complement to the TOMS instrument on the Nimbus-7 satellite. Earlier in the same month, the Shuttle Solar Backscatter Ultraviolet instrument was flown on the Space Shuttle Atlantis, providing space-based measurements of ozone and its vertical distribution. Many of the upcoming NASA Mission to Planet Earth activities are cooperative international undertakings, for example:

(a) In 1992, TOPEX/Poseidon, a United States-French ocean topography satellite, will be launched aboard an Ariane expendable launch vehicle;

(b) In the mid-1990s, another United States Total Ozone Mapping Spectrometer and a scatterometer will be launched on board the Japanese Advanced Earth Observing Satellite;

(c) In the mid-1990s, the Tropical Rainfall Measuring Mission, a United States-Japanese mission, will make a systematic study of rainfall in the tropical regions; and

(d) The United States, Germany and Italy will cooperate in Imaging Radar Experiments during three Space Shuttle research laboratory missions.

The Space Shuttle will also be used for a series of Spacelab missions designated the Atmospheric Laboratory for Applications and Science (ATLAS). The first of these missions took place from 24 March to 2 April 1992 and carried instruments to measure atmospheric and solar parameters related to global change.

Beginning in 1998, the satellites of the first phase will be replaced by a constellation of intermediate and small satellites as part of the Earth Observing System, which is the centerpiece of NASA's Mission to Planet Earth programme. The Earth observing spacecraft are designed to provide data for improving climate models for monitoring the Earth's long-term climatic evolution. Current plans call for increasing system flexibility and reducing risk by deploying a constellation of six spacecraft launched on a variety of expendable launch vehicles. These six spacecraft will carry seventeen instruments that will make simultaneous, global observations of related environmental variables and climate. These observations will be supplemented with extensive, coordinated ground and aircraft measurements.

The Earth Observing System Data and Information System (EOSDIS) is an integral part of the Earth Observing System and is designed to serve the data handling needs of the NASA Mission to Planet Earth Programme. It will process, archive, and distribute data from the Earth Observing System and the Mission to Planet Earth missions that precede it. EOSDIS is expected to serve a worldwide user community that could approach 10,000 scientists.

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F. ISY activities in India

India's ISY activities are focusing on the Global Change Programme. Launches of two Indian Remote Sensing satellites (IRS-1A and 1B) by the Soviet Union in 1988 and 1991 were very important for applications of remote sensing in India. They are now being used in such applications as agriculture, drought and forest management and wasteland and ground water mapping. An IRS ground station at Hyderabad has been augmented to receive data from other satellites such as ERS-1. Satellite remote sensing combined with other methods, has proven to be a very powerful method for monitoring the geosphere and biosphere changes.

Studies to be undertaken by India during ISY will focus on monsoon patterns, snow-melt variations, cloud radiation, greenhouse warming, forest cover monitoring, marine pollution studies, and mapping of flooded and flood-prone areas. Monitoring techniques have resulted in improvements in the control of deforestation and urban sprawl, as well as in monsoon-related matters. India has acquired a vast amount of data through balloon, rocket and ground-based observations, as well as through satellite remote sensing. Other activities planned for ISY included organizing mobile space exhibitions, generating public awareness of global change phenomena, organizing in-depth workshops on ongoing efforts, and setting up training courses on satellite data interpretation and its use in monitoring global change.

G. Problems of contemporary global warming

It can be stated with a high degree of confidence that since the late 19th century the average global mean temperature has increased, but we cannot be sure about the exact magnitude of this increase. This uncertainty arises because of inadequate spatial and temporal sampling and changes in observation methods. The Intergovernmental Panel on Climate Change (IPCC) tried to express this uncertainty by giving a range of warming since the last century of 0.3°C to 0.6°C. It is certain however that this increase of temperature has been irregular over both space and time. Considering only global mean temperature, the 100-year temperature rise is not inconsistent with the lower range of theoretical calculations based on a doubling of carbon dioxide concentrations (or the equivalent in other greenhouse gases), which predict a temperature increase of about a 1°C to 3°C. Such a doubling of greenhouse gases is likely sometime during the 21st century. Closer examination of the temperature record, however, highlights many peculiar characteristics of the observed temperature rise which makes its linkage to an enhanced anthropogenic greenhouse effect uncertain.

Over the past several years the change in the global temperature record has been the central focus in the debate over the effect of increasing concentrations of greenhouse gases. The reason for such attention is quite simple. The clearest signal of an enhanced greenhouse gas concentration in Global Climate Models (GCM) is reflected in the temperature response near the Earth's surface. For this reason, a considerable amount of effort has been expended in reducing and identifying the uncertainties in the historical temperature record, and relating these data to the projections of climate change expected in an enhanced greenhouse world.

The exact magnitude of the global temperature increase over the past 100 plus years is still in question, but not the sign of the change. There are many reasons for the uncertainty in the magnitude of the change, and for some regions of the globe the uncertainty is of the same magnitude as the anticipated future change of temperature due to anthropogenic greenhouse gases. Fortunately, time series used to estimate temperature changes on a continental scale often (but not always) have smaller random errors and biases than do similar time series over smaller space-scales. This can result in situations whereby a

higher degree of confidence is associated with large-scale temperature changes compared with local and regional space-scales.

Uncertainties arise because:

(a) Station locations have changed;

(b) Stations located in the vicinity of human activities are often affected by local modifications of the climate, such as urban heat island effects, that are not representative of large-scale climate variation and change;

(c) The spatial coverage of the data is neither globally comprehensive nor optimally spaced, and the degree of coverage changes over time; and

(d) Changes have occurred in instruments, exposures of thermometers, observing schedules, observing practices, land use and other factors, sometimes introducing systematic biases into the record.

A recent analysis has provided evidence to suggest that human-induced changes in land use, for example desertification, has also impacted the temperature record. Over the past century, human-induced desertification has increased, and it is likely that some of the observed warming in the climate may be directly attributable to large-scale climate forcing. Again however, the impact is much more important on regional and local space-scales than on global space-scales.

Since oceans cover over 70 per cent of the Earth's surface, the uncertainties in the temperature records over the oceans can actually dominate the uncertainties in global temperature change. There are two dominant sources of uncertainty to consider: first, the adequacy of spatial coverage over the oceans; and second, the effect of changes in the observation methods. The first problem stems from the fact that ships of opportunity are the primary source of information about ocean temperature change since the 19th century. These ships have followed preferred navigation routes and consequently leave vast portions of the ocean unsampled. Changes in these routes over the course of the century, as a result for example of the opening of the Panama Canal, are also significant.

Fortunately, some studies have shown that although there may be many important large-scale temperature variability on a time scale of decades caused by spatial sampling, temperature change on a scale of centuries is dominated by a uniform global response in all the oceans. As a result, the importance of poor spatial sampling diminishes considerably when the time-scale is increased. On the other hand, there might be other patterns of global scale variability in the past or to come in the future which have not been manifested in the modern climatic records - such as an asymmetric hemispheric response to increases in anthropogenic greenhouse gases. A recent analysis using the global coverage from the infrared sensors aboard NOAA satellites suggests that even in the most recent decades, we cannot reliably estimate southern hemisphere temperature anomalies using ground measurements.

Additional independent evidence regarding the sign of the long-term global temperature change comes from terrestrial, airborne and space surveys of glacial advance and retreat. Although these surveys lack the important mass balance required for certainty, they suggest that on a global basis, mountain glaciers are in retreat.

The increase in temperature is often summarized as a trend or constant rate of change. But detailed data show that the rate of temperature change has been anything but constant. In fact, almost all of the warming since the turn of the century occurred during the 1920s and 1930s and in the renewed warming

since the late 1970s. During most of the time since the last century, global temperatures have been quite stationary.

One of the major challenges in understanding how temperatures have responded to the global increases of anthropogenic greenhouse gases is related to the timing and abruptness of the observed global warming. It has been shown that the 50-year period associated with the greatest increase of temperature occurred during a period of only modest increases of greenhouse gases, and contrarily, during the 50-year period associated with the smallest increase of global mean temperature, the rate of increase of anthropocentric greenhouse gases is substantially greater. There are two possible explanations to this strange behavior. Either the climate system is quite insensitive to the increases of greenhouse gases which occurred over the last 100 or more years, or other major forcing processes must be at work. This implies that efforts to observe the greenhouse effect and relate it to the observed climate record could be confounded by other factors such as volcanic eruptions, solar radiation variations, other natural climate fluctuations, and other anthropogenic forcing such as the generation of tropospheric aerosols.

One of the more important questions about how temperatures have and will change relates to extremes of temperatures. There have been a dearth of analyses on how changes in extreme temperatures, or in mean monthly maximum and minimum temperatures, have changed over the past century. This stems from the difficulty of compiling records from local daily temperature measurements. Internationally exchanged climate summaries have not included this type of detail. Recently, however, there have appeared compilations of data sets over the United States, the former Soviet Union and China, which include mean monthly maximum and minimum temperatures as well as seasonal extreme maximum and minimum temperatures. These data indicate that virtually all of the warming in these three countries, which comprise nearly 40 per cent of the Northern hemisphere land mass, is due to a rise of the minimum nighttime temperature. Similar time series related to the change in the seasonal extremes of temperature reflect a narrowing of the extremes with minimum temperatures increasing, but little change in the extreme maximum.

The causes of the asymmetric diurnal changes are uncertain. There is some evidence to suggest that changes in cloud cover play a direct role, with increases in cloudiness resulting in reduced maximum and higher minimum temperatures. Regardless of the exact cause, these results imply that either (a) the warming in much of the Northern hemisphere is grossly affected by non-greenhouse forcing, or (b) the climate model projections related to the expected change in the diurnal temperature are underestimating the rise of the daily minimum relative to the maximum. GCMs project an almost symmetrical increase in the daily minimum temperature relative to the maximum temperature.

Therefore, while it is quite certain that global mean temperatures have increased since the 19th century, the exact magnitude is uncertain and remains to be determined by a combination of classical and new observational methods, including global monitoring of environmental parameters from space.

H. Satellite disaster monitoring in China

Images from the Chinese meteorological satellite FengYun-1 together with images from United States NOAA satellites and Japanese Geostationary Meteorological Satellites (GMS) have recently played an important role in natural disaster monitoring and protection. During the 1991 flooding in Eastern China and the 1987 forest fires in Northeastern China, hourly meteorological images were broadcast by the Chinese television network providing valuable information to areas affected by the disasters.

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In June and July 1991, the Yangtze River and the Huai He River in Eastern China experienced severe flooding. A film loop using a sequence of hourly images from the the GMS satellite clearly showed the weather pattern causing the severe precipitation. From June 12 to 15, the total precipitation in the area was 100-300 mm and in some locations more than 300 mm. The water level in the mainstream of the Huai He river rose to 29.56 m, which is the third highest level since 1949. From June 29 to July 12, heavy rains poured down continuously in that region, with total precipitation of about 300-500 mm and up to 800 mm in some areas. That precipitation caused a major flood in the Huai He River and the highest water level in the historical record of Tai Hu Lake. The stable subtropical atmospheric high from the Western Pacific Ocean and a cold surge from the North met persistently over the basins of the Yangtze and the Huai He rivers. Meteorological satellites played two important roles in monitoring the disaster and planning measures to protect the population: (a) as an input to decision-making on flood diversion; and (b) for estimating the flooded area.

On 14 June 1991, after about two weeks of continuous rain, the water level in the Huai He River rose to 29.56 m, which was higher than the water diversion threshold. In accordance with the existing flood control plan designed to ensure the security of a dam and protect major cities and coal mines from flooding, flood waters had to be released. It was originally proposed to open the dam at 1.00 a.m. on 15 June 1991. This decision would give the people in the flood diversion area 6 hours notice to leave their homes and move to safe places above the dam. The furthest distance from the center to the edge of the flood diversion area was 16 km.

Considering that it was night and that due to the rainfall, paths were very slippery, six hours was very short, particularly for old people and children. The State Meteorological Administration was requested to predict the rainfall as the basis for timing the flood diversion. Based on the satellite images and other information, the National Meteorological Center of China issued a forecast that the rainfall intensity would soon be decreasing. It was therefore not expected that the water level would increase rapidly and a proposal was made to open the dam at 8.00 a.m. This suggestion was accepted by the government and as a result, people had 7 more hours to evacuate the areas to be flooded.

After the flooding, the Chinese government needed an objective estimation to the extent of the disaster. Cloud-free FengYun-1 and NOAA images with clear land surface characteristics before and after the flooding were selected and analyzed. Water and land areas were distinguished by their different reflection in channel 2. By careful analysis and field investigation, the increase in the area covered by water for the whole river basin and for 87 counties in the region were calculated. Using a series of images taken on different dates, the dynamics of the flooding was studied in the eastern part of the region. It was found that although the flooded area was very large, the flood waters quickly receded. In the Western part, however, the flood waters subsided very slowly.

In May 1987, Northeastern China had a very warm and dry spring, and a severe forest fire started on 6 May. Due to a strong wind, the fire spread rapidly. On 8 May, the burning was so fierce that extensive fire and smoke made it impossible to evaluate the situation and evacuate people in threatened areas. However, when a NOAA satellite image was received and processed, the overall situation could be clearly seen. On the evening of the same day, this image was transmitted by the Chinese television network as an urgent news bulletin. Satellite images subsequently played an important role in coordinating fire-fighting actions as they were regularly made available at the local command center. After the fire, a NOAA image of 2 June 1987 showed that the area burned by the fire was more than one million hectares.

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In China, satellite images are used not only for weather forecasting and disaster monitoring, but also in many other economic and social activities, such as greenness monitoring for agriculture, snow cover monitoring for water resources in Western China, sea ice monitoring for navigation and petroleum drilling in off-shore areas, sea-surface temperature monitoring for fishing, and sand and sediment distribution monitoring for port construction feasibility studies.

In order to encourage people to understand and use meteorological satellite data, satellite images are regularly shown on the Chinese television network programme, "Meteorological Information," a 5-minute programme broadcast daily. The feedback is mainly from three groups of people: local meteorological station staff indicate that this information is helpful for their forecasts; high school students ask many questions; and the most encouraging letters are received from farmers who use these images for their farming activities. The following is from a letter from a farmer:

> By watching the "Meteorological Information Program," I got some idea of the weather. On 13-14 July 1990, it was clear and dry with a scorching sun overhead. The maximum temperature was about 38 degrees. The corn leaves rolled up. Everyone was impatient for rain. Someone was getting ready to take measures against drought.
>
> At noon on 15 July, "Meteorological Information" showed a cloud cluster moving East. Some villages who watched the program started to use fertilizer in their fields rather than water. In the morning of 16 July, although it was still clear, more and more peasants gave fertilizer. At noon of 16 July, seeing that the cloud cluster was approaching our district on the satellite images, many farmers went out to the field, spreading the fertilizer. The farmers showed confidence in the "Meteorological Information" program. It is impossible for a farmer to gamble with his fertilizer.
>
> In the evening of 16 July, the expected rain arrived. Then we were really happy. We thank the "Meteorological Information" program from our hearts.

Aware of the importance of space meteorology, the Chinese government attaches great importance to developing an indigenous meteorological satellite. After a continuous effort for about two decades, the first and second meteorological satellites were launched in 1988 and 1990. The satellites, called FengYun (FY-1A and FY-1B), were launched into a near-polar, sun-synchronous orbit at an altitude of about 900 km. The satellites are three-axis stabilized, and the cameras have a ground resolution of about 1.1 km and provide images in five spectral channels. The daytime cloud and surface imagery is provided by channel 1 (580-680 nm); water, ice, snow and vegetation observations are best with channel 2 (725-1100 nm); ocean colour images are provided by channels 3 and 4 (480-530 nm and 530-580 nm); and thermal infrared images from channel 5 (10.5-12.5 μm) are used for night cloud imagery, and land and sea-surface temperature measurements. China plans to launch a geostationary meteorological satellite, FY-2, in the mid-1990s. The FY-2 satellite will be spin-stabilized and located over the equator at longitude 105-108°E. The sensor will have three channels, visible (500-1050 nm), thermal infrared (10.5-12.5 μm) and water vapour (5.7-7.1 μm), with a ground resolution of 1.25 to 5 km.

I. Contributions of ERS-1 to environmental monitoring

The European Space Agency's first remote sensing satellite, ERS-1, was successfully placed in orbit by an Ariane launcher on 16 July 1991. It is now starting to make its contributions to International Space Year and is opening up a new chapter in global ocean and ice monitoring from space. After the commissioning, calibration and validation phase, it was found that the radar system and the Along-Track Scanning Radiometer (ATSR) are performing very well and in many respects have exceeded specifications.

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It has been confirmed that the ERS-1 Synthetic Aperture Radar (SAR) can detect ocean, ice and land features similar to those seen previously in radar data from the 1978 Seasat, which used a different radar frequency and polarization. The provision of global data-sets including consistent measurements of sea conditions such as wind, waves and surface temperature is an important achievement. The most complex sensor, the wind scatterometer, is providing very accurate measurements that are currently being validated through a large campaign in the North Sea.

The initial analyses of the data from the Along-Track Scanning Radiometer has confirmed its ability to measure global sea temperature with the accuracy required by climatological models and has indicated an unexpected potential for providing information on land and vegetation cover. The ERS-2 satellite will carry an enhanced ATSR, which should provide additional research and applications possibilities.

ERS-1 has already proved its usefulness for maritime operations by assisting in the routing of a ship through ice-infested waters from Norway east to Japan via the Bering Strait. More recently the ERS-1 SAR instrument was able to detect and monitor the oil slicks that hit the French Riviera in September 1991. In future, it should be possible to integrate oil slick mapping information with data on surface winds and waves to forecast the trajectories of oil spills.

ERS-1 SAR data has already been acquired from the satellite by six ground receiving stations in Europe and ten others around the world providing coverage on all five continents. This large-scale international effort will make it possible to support a wide range of research projects in many critical environmental areas. For example, ice cover in the Arctic can be monitored from six ERS receiving stations already in operation, and data for Antarctica can be acquired by two stations. Using these data, polar ice cover can be monitored to see whether the greenhouse effect is causing a rise in sea level. In addition, six ground stations already operating in the tropical belt, plus a few more that will soon be operational, will provide support for the global tropical deforestation monitoring programme being undertaken in cooperation with the European Economic Community.

The ERS-1 radar data is being used to generate both digital and photographic products. The data processing systems operated by ESA, Canada, the United States and Norway are now distributing data to scientists selected by ESA through an announcement of opportunity process as well as to all other interested users. The data collected by ESA is being archived at Oberpfaffenhofen (Germany), Farnborough (United Kingdom), Matera (Italy) and Brest (France).

Commercial distribution of ERS-1 data will be through a group of companies that have been designated by ESA for data marketing and sales: Eurimage in Italy, Radarsat International in Canada, and Spot Image in France. Eurimage will cover Europe, North Africa and Middle East; Radarsat International will cover North America; and all other countries will be covered by Spot Image.

J. The ISY World Forest Watch

Forests are important for preservation of the global environment and for forest-based industries. The effective management of forest resources requires (a) mapping of various forest types by species and extent; (b) detection and delineation of forest areas damaged by fire, disease or excessive cutting; and (c) estimation of potential production.

Estimates of the deforestation rate in the Brazilian Amazon region over the last few years have varied by a factor of four. More reliable estimates are needed because of deforestation's substantial contribution to global concerns such as greenhouse warming and loss of biodiversity. Recent estimates made with Landsat images seem to represent the most reliable values to date. Although the Landsat data indicate that the forest clearing rate is lower than some previous estimates, the pace of forest loss is still high.

Protecting the environment requires a permanent forest monitoring system using satellite images, especially over critical areas of high deforestation, as well as for national parks, Indian reserves, mineral exploration areas and water reservoirs. To meet this requirement, a World Forest Watch (WFW) project is being developed in conjunction with International Space Year. The project is being coordinated by the Brazilian Institute for Space Research (INPE) and the Joint Research Center of the European Commission and will involve several other space and research organizations worldwide. The project includes a global forest monitoring component using NOAA-AVHRR data and a regional forest monitoring component using Landsat and SPOT data. The global component will cover West and Central Africa, South America, and South and Southeast Asia. The regional project will cover the Amazonian forests in Brazil, Bolivia, Peru, Colombia and Venezuela. The first results of the WFW project will be presented in May 1992 during the World Forest Watch Conference in Brazil.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

A. Remote sensing applications for hydrology

The National Operational Hydrologic Remote Sensing Center in the United States creates and distributes a variety of remote sensing-based information products in support of the hydrologic services of the National Weather Service (NWS). The most widely used products are the estimates of snow cover derived from airborne and satellite sensors. The Center operates two gamma-ray detection systems on low-flying aircraft to determine snow-water equivalent over portions of 25 states and Canadian provinces. Analysts also use image data from the Advanced Very High Resolution Radiometer (AVHRR) on the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites and image data from the Geostationary Operational Environmental Satellites (GOES) to produce digital maps of snow cover for over 4000 river basins in the United States (including Alaska) and in Canada.

The Center's satellite receiving station in Minneapolis receives live AVHRR data from NOAA polar-orbiting satellites during their passes over all of the United States and Canada. The data are radiometrically calibrated and geographically registered to one of 24 standard "windows," each of which is approximately 1000 km by 1000 km. Satellite analysts at the Center use spectral bands 1, 3 and 4 of the AVHRR data to classify areas of the image into snow, no-snow, or cloud. The classified image is then integrated into a geographic information system that includes digital elevation model (DEM) data and hydrologic basin boundary maps. Automated procedures calculate the per cent snow cover in each of about five elevation zones for each of more than 500 major river basins in the western United States and Alaska. Snow cover is also mapped for river basins in the upper Midwest, the Great Lakes, New England and Canada.

The Center distributes these satellite-based snow cover products weekly for regions where snow cover is a significant hydrologic variable. The products are distributed electronically, in near real-time, to end-users in both alphanumeric and image format. The end-users can then issue spring flood predictions, water supply projections, and river and reservoir inflow forecasts for the region.

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Field hydrologists receive the airborne and satellite snow cover products approximately two hours after the snow survey aircraft land anywhere in the country or two hours after either the morning or afternoon overpass of the NOAA satellite. In addition, personnel at the Center generate snow cover maps from AVHRR and GOES satellite data for all 24 windows approximately once a week, although snow cover information for some areas may be obscured by persistent cloud cover.

Each summer, the Center distributes to end-users a CD-ROM that contains the previous season's airborne and satellite snow data. The CD-ROM includes: (1) airborne snow-water equivalent data and the digitized flight line network; (2) calibrated AVHRR and GOES satellite data used to map snow cover; (3) the classified snow cover images; (4) national and regional snow cover image products; and (5) ancillary data sets including digital elevation data, digitized NWS basin boundaries, and the alphanumeric results of the satellite snow cover mapping by basin and by elevation zone.

The Center has recently developed the capability to generate and distribute, in real-time, raster (or grid-cell) snow-water equivalent data sets using: (1) ground-based point snow-water equivalent data; (2) airborne flight line snow-water equivalent data; (3) satellite snow cover area data; (4) digital elevation data; and (5) forest canopy cover data sets. By combining these diverse data, this new product makes it possible for hydrologists to extract the maximum information from the available data sets and to incorporate the remotely sensed hydrology products into conceptual hydrologic models used in operational and research hydrology programmes.

In the future, the Center will further develop and refine the remote sensing hydrology products to incorporate information derived from advanced radar data and from Special Sensor Microwave Imager (SSM/I) satellite data. These and other data from future remote sensing technologies will be incorporated into operational, real-time, hydrology products. All of the remote sensing estimates of parameters affecting national water resources are being fully integrated into NWS plans for an enhanced Water Resources Forecasting System (WARFS).

B. Remote sensing for sustainable development in India

Sustainable development of natural resources is based on maintaining the fragile balance between economic production and resource conservation through monitoring and identification of problem areas that require alternative agricultural practices, crop rotation, use of bio-fertilizers, energy efficient farming methods and reclamation of unused lands. Sustainable development requires a holistic approach that maximizes crop yields while taking into account environmental conditions.

As part of the effort in India to use satellite remote sensing for integrated development, surveys are being conducted using a combination of conventional and remote sensing techniques. The first phase of the survey consists of collecting and evaluating conventional data. The second stage involves the preparation using remote sensing data of a set of resource maps, including (1) surface water bodies; (2) ground water potential zones; (3) potential zones for ground water recharge; (4) soils and erosion; (5) existing land use and distribution of wastelands; and (6) an integrated land and water resource map indicating high-priority areas for agricultural development, fuel and fodder production, soil conservation and afforestation. The final stage is to develop a package of appropriate strategies to address local resource management and environmental problems. The integrated development programme presently covers 18 districts of India, covering about 17 million hectares representing diverse terrains, agro-climatic zones and social practices.

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Sustainable integrated development of vast rural areas and increasing the productivity of land and water resources is only possible when the farmer is able to appreciate and assimilate new scientific ideas into his culture and when rural society as a whole is educated. The task is further complicated in most developing countries because of fragmented land holdings, which make it difficult for farmers to provide adequate inputs. While about two million farmers are cultivating over 200 million hectares of agricultural land in the United States, in India 168 million hectares of land is distributed among 100 million farmers.

It is only when rural farming families cooperate in managing their valuable land and water resources that adoption of ecologically sound technologies, such as integrated pest management and nutrient supply, on small holdings will become practicable. Many conservation projects employed so far have failed because they have only addressed symptoms and not causes of land degradation and because agricultural practices were imposed from the top without caring for cultural sensitivity and the involvement of local communities.

Illiteracy in most developing countries will continue to be 30 per cent or more even in the year 2000 unless new and revolutionary ways of mass education are used to eradicate illiteracy quickly. The Indian Space Research Organization (ISRO) is working on a new approach to distributing audio-visual media via a dedicated satellite called GRAMSAT, which will be designed to meet the needs of rural areas for culture- and region-specific knowledge in the areas of health, hygiene, environment, family planning and improved agricultural practices in each of the regional languages.

The GRAMSAT system, in addition to providing continuing education for special groups to update their technical skills, will also provide linguistic minority groups with access to programmes in their own languages. Development of continuing education programmes and retraining of rural teachers, medical personnel, technicians and industrial workers requires a two-way communication system through which inter-active instruction can be established and questions can be answered by experts to clarify doubts. Inexpensive hardware has been developed for this purpose and tested in Gujarat state, where village leaders and teachers in a remote village were able to interactively communicate with other teachers at the Space Applications Centre in Ahmedabad.

The GRAMSAT satellite will carry six to eight 6/4 gigahertz transponders, which will distribute television programmes to local rebroadcasting stations for reception on ordinary television sets in each house or village. Using video compression techniques to increase the number of channels that can be carried by the satellite, the broadcasts will cover 90 per cent of the national population with programming in each of the regional languages. Linguistic minorities outside their language region will be able to receive programmes in their language by means of direct satellite reception with a 2-meter antenna. The use of two or three very-high-power, spot-beam, 14/11 gigahertz transponders will allow direct reception with antennas as small as 0.8 meter antenna. This capability will be particularly useful for continuing education of industrial workers in urban areas.

While the hardware required for the system hardware can be produced easily, production of interesting and entertaining educational programmes in each language is more difficult. India's own experience in the Satellite Instructional Television Experiment (SITE) in 1975-1976 has amply demonstrated that educational programmes need not be drab, but can be highly entertaining, particularly when imaginative use is made of the vast available resources of cultural heritage, folklore, street drama, mythology, and rural anecdotes. It is hoped that GRAMSAT and similar programmes will catalyze a new revolution in India and transform the dormant society to a new awakening.

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C. The Global Change Encyclopedia

The Global Change Encyclopedia (GCE) project was initially developed by the Canada Centre for Remote Sensing and subsequently proposed by the Canadian Space Agency as a Canadian contribution to International Space Year. It will also contribute to the goals of the International Geosphere-Biosphere Programme. The objectives of the GCE project are:

(a) To increase the awareness of the world's population about the value of space observations for the study of the environment, especially in the context of global change; and

(b) To make it possible for students, teachers, scientists and the public to become acquainted with satellite data, digital image analysis, geographic information systems, and the use of digital and ancillary data for environmental analysis, including socio-economic aspects.

The basic form of the Encyclopedia will be a set of CD-ROMs (compact disc read-only memory) containing data together with software to manipulate the data. In addition, a subset of the data will be produced on ten computer diskettes as a demonstration package for users without access to CD-ROM readers.

The various GCE data sets will be co-registered in an internally consistent data base using a geocentric projection with a latitude and longitude grid. This will permit the user to extract, from the various data sets, information available for a defined area of interest. The GCE data sets will concentrate on consistent, long-term satellite data representing environmental parameters such as ocean colour and temperatures with comprehensive coverage for the 1985-1989 period. In all, 32 different sets of satellite-derived information will be included, ranging from snow cover, soils, vegetation, and ocean wave heights to aerosol emissions, wetlands, and socioeconomic data.

Special emphasis will be given to socio-economic data on a world-wide basis. These data include population, agricultural productivity, energy production and consumption of non-renewable resources. Sources include the United Nations and the World Resources Institute. To make a link between the sometimes abstract satellite data and the Earth's surface that is familiar to future GCE users, photographs of relevant features will be included occasionally as part of the data set. These will represent themes such as endangered species in various parts of the world and will be referred to the proper geographic locations using software tools.

Software will be provided as part of the GCE to allow manipulation of single and combined data sets. The user will be able to use such image processing techniques including visual display, zoom, enhancements, classification and overlays. The system will also be able to capture, store and display annotation. The user will also be able to use data processing programs from other sources to manipulate the GCE data.

The GCE software will make interaction possible at several levels: demonstration, browse, exercise and command. The basic level, demonstration, will be a guided tour through the GCE package. At the browse level, the user can display entire global images or a subset of global images, overlay thematic data, query as to geographic position and data value, and make composite profiles of several data layers. The user interaction at these levels must be simple and enjoyable for the users in order to maintain their interest. Both levels will be available in diskette and CD-ROM versions.

At the next level, exercise, the user can analytically derive a theme by executing a short series of map overlays following prompts by the computer. The user will thus be able to gain insight into the

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parameters influencing environmental processes and phenomena and will also be stimulated to experiment. The highest level, command, is intended for users familiar with the GCE package who wish to perform analyses of their own design. This resembles the command level operation of most low-cost geographic information systems. The exercise and command levels will be available only in the CD-ROM version.

A GCE demonstration product should be available by summer 1992. It is anticipated that the distribution will be worldwide, and efforts are being made to ensure that GCE will be relevant and interesting in a school environment. English and French versions of the software will be available. The GCE package is intended for PC/AT-type personal computers with a minimum of 640K RAM, 20MB hard disk and an EGA graphic card. As far as possible, the data will be in a format that can be accessed by non-PC computer systems.

In addition, a hard copy of the encyclopedia called the Global Change Atlas is being prepared for those without access to computers. The images will be accompanied by text with general explanations describing what global change is and what the changing image of the Earth shows, "from the Egyptian map to a space map." Satellite image maps will be liberally used in the Atlas, but they will be referenced to conventional maps.

D. Life sciences and space medicine

The past year was very rewarding for the NASA Life Sciences Programme. By continuation of the programme's stated goals - assuring the health, safety, and productivity of humans in space and acquiring fundamental knowledge in the space biological sciences - it was possible to further contribute to the health and well-being of people on Earth. The Spacelab Life Sciences mission (SLS-1), which flew in June 1991, was the first Space Shuttle mission dedicated entirely to space life sciences. With 17 primary experiments, it was also the first comprehensive set of interrelated physiological studies in space since the 1973 Skylab mission. Investigators from Australia, Canada, France, Germany, the Russian Federation, Switzerland and the United States conducted flight experiments. The results of SLS-1 have provided new insights into human adaptability to extreme environments, and will provide a better understanding of the health parameters that should be monitored in space.

A second mission of major importance was the January 1992 International Microgravity Laboratory mission (IML-1). Thirteen countries contributed experiments to the mission which featured an international crew consisting of astronauts from Canada, Germany (representing ESA) and the United States. NASA's international partners - the European Space Agency and space agencies of Canada, France, Germany and Japan - contributed eight major research facilities to IML-1. The mission was devoted to life sciences and material sciences, with the primary objective of studying the effects of microgravity on living organisms and materials processes. The life sciences investigations addressed a variety of topics in human physiology, human performance and the space radiation environment.

Another very important area of space life science investigations is telemedicine, a term used for the combination of electronic medical monitoring systems and communications. Telemetry is used to monitor the electro-cardiograms and other vital signs of astronauts during a spaceflight. Since 1971, modern health care systems have used space technology to provide physician consultation capability for patients in remote areas or at small medical facilities. Reliable physiological monitoring and communications permit a largely dispersed population to benefit from a limited supply of highly trained personnel. In December 1991, the United States hosted a Telemedicine Conference in Bethesda, Maryland, which

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attracted specialists and policy makers from around the world. The conference helped set an agenda for the future of telemedicine and disaster medicine.

The Malaria Project is an example of the effective applications of space technology and telemedicine. The Malaria Project is a part of the Biospheric Research Programme, which studies Earth as an integrated biochemical system. The Project's goal is to demonstrate that remote sensing and geographic information system modeling techniques can be used to monitor and predict potential areas of high disease transmission. The research conducted to date has demonstrated the potential application of remote sensing data to better understand and respond to world health problems.

E. Alternatives to geostationary orbits

There are many communications satellites which use geosynchronous circular orbits with a small inclination to the equatorial plane. Ideally, the orbits would be truly geostationary, i.e. with zero inclination, but it was found more cost-effective to tolerate a change in inclination of around 7° over the spacecraft's lifetime rather than to provide the additional fuel needed for north-south station-keeping. The attraction of a quasi-geostationary orbit is that the satellite always appears at more or less the same position in the sky. Hence the ground stations do not have a severe tracking requirement, and, equally important, a single satellite can provide continuous service to all ground stations within its "footprint" covering about one-third of the Earth's surface. This means that such a satellite positioned around 18°W longitude can provide continuous coverage of most of Europe and the North Atlantic. It would be visible at useful elevation (at least 8°) from earth stations located in the capitals of the countries of this region.

There are several reasons why alternatives to these quasi-geostationary orbits are worth considering, namely:

(a) New operational requirements may imply a need for the extension of communication coverage into to high norther or southern latitudes;

(b) The problems of coordinating satellite locations on the geostationary arc and of avoiding interference are becoming severe, particularly at super-high-frequencies (SHF);

(c) At extremely-high-frequencies (EHF), the low elevation at which a geostationary satellite is seen from North America and Northern Europe means that a satellite earth station at these locations will suffer high atmospheric attenuation and be particularly susceptible to outages in rain;

(d) There are several advantages in using inclined orbits for defence communications satellites.

Inclined highly-elliptical orbits (HEO) have been used by Russian Molniya satellites since 1965. At apogee, such a satellite is typically around geosynchronous altitude whereas at perigee its altitude may be only a few hundred kilometers. The satellite's movement near apogee closely approximates the pace of the Earth's rotation for several hours and thus it maintains a fairly constant "footprint" during this period. Continuous coverage can therefore be provided using only a small number of active satellites.

The typical orbital period of Molniya satellites is 12 hours and with a perigee altitude of 1000 km which corresponds to an eccentricity of 0.726. In a system with 12-hour orbits, each satellite provides coverage of the service area at alternate apogees, i.e. every 24 hours. Because the operational period of each satellite is necessarily less than the orbital period, at least three satellites are needed to provide continuity. A major advantage of the Molniya orbit is that an apogee boost motor, used to circularize the

orbit of a geosynchronous satellite, is not required. Typically this accounts for about half the mass of the satellite at launch.

Systems with orbital periods grater than 12 hours are also possible. The basic requirements are that all satellites in the system should follow the same ground track, and that there should be sufficient satellites for at least one to be visible at all times from the desired service area. This could be achieved, for instance, with two satellites in 24-hour orbits. Consideration has also been given to a system based on 16-hour orbits in which each satellite provides service for eight hours around the relevant apogee. Since it takes 48 hours for a satellite in a 16-hour orbit to repeat its ground trace, six satellites are required.

Because the Earth is not a perfect sphere, its gravity field is not completely regular and each of the parameters defining a satellite orbit therefore changes with time. For communication applications, the Earth's flattening causes the orbital ellipse to rotate within the orbital plane, thus changing the position of perigee. The rate and direction of this rotation depends on the mean height of the orbit (semi-major axis) and on its inclination to the equator. It can be shown that for an inclination of 63.43°, this rotation vanishes (for smaller inclinations the rotation is counterclockwise and for greater inclinations clockwise). Thus, if the orbit is chosen to have this "critical inclination," the rotation tendency is eliminated, at least to a first order. Russian Molniya satellites use exactly this inclination.

For other inclinations, it is possible to calculate the change in velocity needed at the appropriate point on each orbit in order to restore the original position of perigee. The amount of fuel required to produce a given change in spacecraft velocity is defined by the "specific impulse" of the fuel. This consumption was found to be unacceptably large even for small deviations from the critical inclination. For example, a 1000 kg spacecraft in a 12-hour orbit with an inclination only 0.3° greater than the critical angle would need to use 0.4 kg of fuel per day to overcome that rotation. For a 12-hour polar elliptical orbit, the requirement increases to a massive 4.6 kg/day. Even though a great economy in mass can be achieved by maintaining a precise orbit by use of "ion thrusters," a 63.43° orbit is the type preferred for most applications. Such an orbit has no disadvantages.

In a system of two or more satellites in inclined elliptical orbits the ground segment must cope with a change of operational satellite several times per day. One way to dealing with this requirement is to provide each earth station with two antennas so that both satellites can be tracked simultaneously prior to switch-over. An alternative technique is to arrange for the rising satellite (that coming into service) and the setting satellite (that going out of service) to pass sufficiently close to each other so that both briefly appear within the beam of the earth station antenna. At the moment of closest approach, the transponder of one satellite could be turned off and that of the other satellite turned on. At the same time the earth station would cease tracking the setting satellite and begin to track the rising one. Provided the system could tolerate, or compensate for, the discontinuities in delay and Doppler shift at the moment of switch-over, it would be possible to maintain links through the transition without interruption.

The coverage of a three-satellite, 12-hour HEO system with 63.43° inclination and with the eccentricity chosen to cause conjunctions every 8 hours could include almost all of Europe, the North Atlantic, the Mediterranean and the North Polar regions. This is considerably better than the coverage provided by a geostationary satellite. While not able to satisfy the "periodic conjunction" criterion, elliptical 24-hour orbits inclined at 63.43° may still offer good coverage of the Northern Hemisphere with a system of only two active satellites.

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The coverage of the 63.43° inclined, 24-hour orbit system may be improved by varying the perigee altitude (and hence the eccentricity) to make the ground trace more compact. This is the principle of the "TUNDRA" orbit, which is being considered for a Canadian communication satellite system. By increasing the perigee altitude to 20,000 km, the ground track could be restricted to an area measuring about 45° in longitude by 30° in latitude during the 12-hour operational period. It is interesting to note that a system called LOOPUS (Geostationary Loops in Orbit Occupied Permanently by Unstationary Satellites) is being studied by Germany for a public mobile satellite network covering the northern hemisphere. Consideration is being given to the use of 12-hour and 16-hour satellites in 63.43° orbits.

Various space-tether concepts were put forward between 1960 and 1980. These included tethers that conserved or generated propulsive power for satellites, tethers that served as ultra-low and extra-low frequency antennas in space, and tethers that connected two or more satellites in a single geostationary arc position. To date, however, no practical implementation of tether systems have been achieved largely due to material weight and strength considerations.

The system having the most promise and application for satellite communications is a geostationary system of tethered satellites aligned along an Earth radius line. The satellites would be located above and below the geostationary orbit in a balanced way so they maintain the necessary geostationary orbital speed. Proponents of such a system have claimed that the number of satellites which could be located at a single orbital position could be increased by a factor of thirteen and could alleviate geostationary congestion at the most used locations.

Implementation of such tethered satellite systems still requires resolution of problems of tether material weight and strength and immunity to micrometeor damage as well as stability during deployment and in operation. These problems apply primarily to tethers that would constitute connecting links between satellites and would therefore be subjected to strong forces. Simple optical fibre links might be used to carry data or control signals between independently controlled and stabilized satellites.

F. The space environment

The space environment around the Earth is populated by natural debris (micrometeorites) and human-made debris. The problems associated with the growing amount of human-made debris has been attracting the attention of many investigators and agencies for some time. The main source of data on debris is the Space Surveillance Network operated by the United States Space Command which at present tracks about 7100 objects. However, this tracking network can only track objects larger than 10 cm in diameter at 1000 km altitude, or 4 cm in size at 400 km altitude. Smaller debris cannot be tracked systematically by the present systems. It is estimated that there are about 20,000 to 70,000 untracked objects on the order of 1 cm in size and larger numbers of even smaller objects.

A theoretical study was initiated in India to model debris generation caused by the disintegration of space objects or by collision between objects. It is estimated that remnants from such events account for nearly 44 per cent of the total catalogued debris and 57 per cent of the low-orbit debris. The study could help to generate a better understanding of the untracked debris environment and to predict collision probability for operational spacecraft.

The study assumes that fragmentation is complete and leaves no large unfragmented debris and that the number of tracked fragments from these events is known. Velocity increments added to the velocity prior to fragmentation provide new velocities for individual fragments and determine their orbital

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altitudes, taking into account that the resulting orbits are not generally circular. In order to get a meaningful distribution, the debris are classified by different altitude bands of, for example, 20 km height. This procedure is repeated for all the fragmentations.

About 33 major in-orbit spacecraft fragmentations, out of the 90 break-ups reported so far, were simulated and compared with observations. The density peaks are clearly noticeable at 800 km, 1000 km and 1500 km. The important feature of this simulation method is that the distribution of debris in various size categories could be studied. It was shown in the case of the break-up of Cosmos 1691 that the trackable objects forms only 2.2 per cent of the total number of fragments. This corresponds to the results of similar independent studies and further emphasizes the importance of preventing break-ups and collisions of larger objects in orbit.

The situation is quite different in the geostationary orbit than in low orbits, as has been pointed out by Czechoslovakia. There are three different scenarios of possible close encounters or collisions. The first is between two active satellites, the second is between one active satellite and one inactive trackable object and the third is between an active satellite and a non-trackable object. Active geostationary satellites are located within about 0.1° of their nominal longitudes. In some cases the same longitude is assigned to more than one satellite, in which case it is up to the operators of the satellites to coordinate their station-keeping maneuvers so as to avoid collisions. There is at present no general rule on how to proceed.

In the second scenario, the probability of a collision between an active satellite and an inactive body depends on their numbers. For a sample of 100 active and 100 inactive objects, it was calculated that one collision would occur in 500 years. However, the present occupation of the geostationary orbit is much higher; the total number of trackable objects is close to 400 and is equally distributed between active and inactive objects. Therefore the present probability of collision is about one every 100 years and is increasing. The actual probabilities may be higher than the above values for several reasons. Firstly, the above values are averages and the collision probability may be higher at longitudes where many satellites are crowded. Secondly, the above values apply to satellites of present sizes. The probability of collisions will increase as the size of satellites increases.

Close encounters between active satellites in the geostationary orbit in which avoidance manoeuvres were initiated have already been reported. These manoeuvres are costly because they use fuel needed for station-keeping, and once the fuel is used up, the satellite cannot be maintained at its nominal position. There are also some problems with the accuracy of orbital tracking and computation methods involved when different organizations are responsible for the control of satellites located in close proximity.

The third scenario deals with non-trackable objects. At the distance of the geostationary orbit, these are all objects smaller than one metre. Their precise number is unknown, but according to investigations in Japan, the debris generated in the geostationary orbit stay close to the orbit and spread within weeks to all longitudes. The relative speed at collision is roughly equivalent to that of two jet planes colliding head-on. Debris generated at breakup will stay permanently near the geostationary orbit and might produce successive collisions. If an explosion occurs in the orbit, the debris will cover the whole belt around the Earth and cascading collisions will likely take place. Since there is no feasible technology which would eliminate small debris, the cascading process would continue until all the mass now in the geostationary orbit, over 200 tons, turn into a debris ring. It is therefore most urgent to discuss actions to prevent breakups or, at minimum, to reduce collision probabilities.

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One of the measures under consideration is boosting satellites that are approaching the end of their active lifetime into disposal orbits beyond the geostationary belt. This method was first used 15 years ago by Intelsat. Since that time several other agencies have used it successfully in some 30 cases. There is, however, no general recommendation concerning the removal of objects from the geostationary orbit.

G. Satellite astronomy and astrophysics

The National Aeronautics and Space Administration (NASA) of the United States has embarked on an extensive program to study the universe across the electromagnetic spectrum. The purpose of the programme in Space Astronomy and Astrophysics is to further human knowledge about the universe, especially relating to how it began, how it evolved to its present state, and how it will change in the future.

The so-called Great Observatories form the core of the NASA program. These are designed to provide observations across the whole electromagnetic spectrum with unprecedented sensitivity, angular and spectral resolution. The first such observatory, the Hubble Space Telescope (HST), was built in cooperation with the European Space Agency (ESA) to provide the international scientific community with a view, unhampered by atmospheric distortion, into the visible and ultraviolet portions of the spectrum. As it approaches the second anniversary of its launch, HST has proven to be one of the most productive astronomical observatories ever built. Well over one hundred observing programs, involving scientists from approximately twenty-four nations, have been completed. Discoveries made by HST are shedding light on a diverse range of phenomena including planetary weather, the physics of stellar atmospheres, the dynamics of star clusters and galaxies, the possible existence of black holes, and the large-scale structure of the Universe. Armed with these and complementary discoveries from other observatories, theorists are developing new insights into the evolution of our universe from the Big Bang to the present, and beyond.

The second Great Observatory, the Compton Gamma Ray Observatory, was launched in April 1991. Built with German participation, Compton studies some of the most exotic and energetic structures in the universe. Gamma rays are the highest energy form of electromagnetic radiation and thus are emitted only by very hot or energetic objects. Compton has detected gamma rays from known sources like pulsars (rapidly spinning, extremely dense remains of dead stars) and quasars (energetic cores of distant, young galaxies). Perhaps most interesting, though,, are the nearly 300 gamma ray bursts so far detected by Compton. Lasting only a few seconds, these bright bursts seem to come randomly. To date, their origin remains a complete mystery.

The two planned Great Observatories, for the X-ray and infrared portions of the spectrum, would complete the in-depth survey of the heavens. The Advanced X-Ray Astrophysics Facility (AXAF) is currently under development, with launch planned for 1997. AXAF will provide far greater sensitivity than its predecessors, including the now-operating Roentgen Satellite (ROSAT). Planning for the fourth Great Observatory, called the Space Infrared Telescope Facility (SIRTF) is currently on hold.

The Explorer programme complements the Great Observatories effort. It consists of moderate and small sized spacecraft designed to fill crucial gaps in the current understanding of the universe. Two recent successes in this programme include the ROSAT mission, a cooperative effort with Germany, and the Cosmic Background Explorer (COBE). COBE has already provided data offering strong confirmation of the Big Bang theory. It has also provided a great puzzle to theorists who are trying to explain the origin of large-scale structure in the Universe. The next satellite, the Extreme Ultraviolet Explorer

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(EUVE) is being readied for launch later this year. EUVE will open an almost completely unexplored spectral window, allowing a study of the structure and composition of the local interstellar medium, nearby hot stars, stellar atmospheres, and white dwarfs.

NASA has also recently embarked on a vigorous effort to enhance the dissemination of scientific discoveries to the public. A new Initiative to Develop Education through Astronomy, or IDAE, seeks to promote education at every level by using the excitement of astronomy as a motivational and pedagogical tool. In addition, this effort should help promote education not only in the United States, but worldwide. The International Space Year project "Mission to the Universe" is designed to share the adventure of astronomical discovery with all citizens of the world.

H. Planetary exploration

Direct exploration of the solar system by robotic spacecraft forms an important part of the United States space programme and involves broad international cooperation. The radar exploration of Venus by the Magellan spacecraft, for example, involves the participation of scientists from Australia, France, the United Kingdom and the Russian Federation. Magellan went into orbit around Venus on 10 August 1990 and since then has revealed surface features as small as 100 metres across. A special data management and archive team has been established by NASA to manage the large quantity of products, including magnetic tapes, photographs, optical discs, maps and hard-copy listings, that will result from the Magellan mission. Data from the first mapping cycle should be released on 62 optical discs at the beginning of 1993.

NASA recently published the first global maps of Venus, clearly displaying impact craters distorted by the thick atmosphere, volcanoes shaped like pancakes, intricate networks of fractures and a mysterious lava channel that extends 6,800 kilometres across the planet surface. Although surface winds on Venus blow at no more than a few kilometres an hour, wind streaks appear around many craters. These streaks generally point toward the equator, indicating the direction of the prevailing atmospheric circulation. Windblown dust may cause erosion or may stick to the rock on Venus's 475°C hot surface. Traces of chemical erosion have also been detected.

Although the Venusian surface is covered with large seemingly unaltered craters, such as the 50-kilometre wide Cunitz crater named for mathematician Maria Cunitz, Magellan has found only about 850 craters on Venus, far fewer than on the Moon or Mars. Planetary scientists speculate that small meteors disintegrate in the atmosphere and larger craters may have been buried by ancient lava flows. One of the most spectacular features on Venus is the Gula crater, named after an Assyrian goddess. Gula extends hundreds of kilometres across but only about three kilometres high. Early in the mission, Gula was thought to be a volcano, but when Magellan radar instruments provided a closer look, they revealed an impact crater and bits of ejecta lying atop the lava flow around Gula and Sif, its sister volcano.

Lofty locations, such as the top of Gula, appear bright to Magellan's radar. Several scientists have identified iron sulfide or iron oxide, which are efficient radar reflectors, as the likely materials covering Venus's highest mountains. Interestingly, Maat Mons, which is the second highest mountain on Venus, appears dark at the top. It might be covered by a dark lava material that has not yet weathered into radar-reflective materials. If that is indeed the case, Maat Mons is younger than other Venusian volcanoes.

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Topographic features on Venus seem to be dominated by the upwelling and downwelling of material in the planet's interior. Upwelling produces circular fractures, called coronae. What appear to be trenches at the edges of some coronae might be places where crust is subducted into the Venusian mantle. A map of Venus's northern hemisphere reveals bright, highland features, such as the well-known Maxwell and Aphrodite regions. These elevated regions may have formed as cool material sunk into the planet's mantle, crumpling the overlying crust in the process.

It was announced on 30 August 1991 that a large landslide had been detected on Venus by comparing radar images taken approximately eight months apart. The landslide might have been triggered by seismic activity caused by volcanic action. The discovery was a fortuitous result of the process of putting together pairs of radar images in order to produce stereoscopic views.

Despite the wealth of data released, the Magellan mission is far from complete. The project is divided into roughly eight-month (243 days) cycles, corresponding to the time it takes for Venus to rotate once with respect to the spacecraft's orbital plane. Cycle 1 - the prime mission - was completed on 15 May 1991, and 83.8 per cent of the planet's surface was mapped during that time. A second round of mapping, completed on 4 January 1992, filled in most gaps in the first map, and some 94 per cent of the surface has now been covered now. The duplicate coverage allows researchers to search for surface changes. A third cycle started on 24 January 1992. Overcoming some technical and financial problems, the Magellan mission is likely to continue for several more mapping cycles.

The Galileo spacecraft, a joint NASA-German effort with substantial cooperation from Canada, France, Sweden, and the United Kingdom is embarked on a complicated trajectory to Jupiter where it will spend 22 months investigating the structure and the physical dynamics of the Jovian atmosphere and conducting detailed studies of the planet's sixteen moons. Following the first gravity-assist fly-by of the Earth on 8 December 1990, Galileo will make one more pass by the Earth on 8 December 1992 in order to further increase its velocity and reach the Jovian system on 7 December 1995.

On 29 October 1991, the Galileo spacecraft obtained data from the first-ever encounter between a spacecraft and an asteroid. That day, at a relative speed of 8 kilometers per second, it passed at a distance of 1,600 km from asteroid Gaspra. Unfortunately, the spacecraft's antenna is only partially open, crippling its communication capability. For now, the spacecraft relies on a small, auxiliary antenna to communicate with Earth, sending results at no more than 40 bits per second, as compared to the planned 134,000 bits per second. At this rate, recovering the nearly one billion bits of scientific data collected during the brief encounter would take more than 8 months of non-stop receiving. Consequently, scientists had not expected to see any pictures of the asteroid until the late 1992 fly-by of the Earth when data could be dumped to ground antennas at close range.

However, mission directors at the Jet Propulsion Laboratory (JPL) had such confidence in the flyby's targeting, that they decided to call back a single photographic frame believed to contain a reasonably detailed view of the small asteroid. A test strip from the image received on 6 November 1991 showed that Gaspra was really at the very center of the camera's field. With the concurrence of other spacecraft teams, who provided up the needed tracking time, NASA's 70-meter antenna in Australia labored for the next eight days to acquire the four-colour portrait.

Galileo took 150 images as it approached Gaspra, though only three dozen are expected to show portions of the asteroid. The many blank images resulted from not knowing exactly where to point the camera during Galileo's snap-shot session. Once the historic images had been received, scientists started

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its evaluation. About 20 by 12 by 11 kilometres in size, Gaspra is a little larger than expected, but every bit as elongated. Gaspra's surface reflects about 20 per cent of the incident sunlight.

Gaspra's irregular, faceted shape argues that the object has not survived intact from primordial times but is instead a fragment from a larger parent body shattered by collisions long ago. An assessment prior to the encounter suggested that Gaspra's current surface should be well under 1 billion years old, quite young compared with the age of the solar system. Based on the roughly thirty-six craters visible and the large, smooth areas between them, mission scientists agreed that Gaspra has probably spent only 300 to 500 million years in its present state. Some scientists suggested that the surface might be thickly blanketed by pulverized rock. Others argued that such a layer can be no thicker than a metre or two on average because the escape velocity on Gaspra is a mere 10 meters per second, and even the gentlest impact would send debris flying off irretrievably into space.

Another intriguing aspect of Gaspra's appearance is its uniform surface colour. Ground-based spectroscopic work had classified it as an S-type asteroid - one thought to consist of a mixture of silicate minerals and metal. Some specialists believed that metallic iron exists on Gaspra's surface and that the asteroid was probably hewn from the lower mantle of a larger precursor whose interior had segregated into compositionally distinct layers. Therefore, Galileo scientists are scrutinizing the image for color changes that might signal compositional variations. Crucial to this quest is Galileo's near-infrared mapping spectrometer (NIMS), an instrument well equipped to discern the mineralogical makeup of different parts of the surface. The currently available NIMS data confirm the presence of metal-rich silicates and thus the overall S-type character of Gaspra. For further data, scientists are awaiting the relay to earth in late 1992 of a complete set of images and NIMS observations.

During the second Earth fly-by on 8 December 1992, a mere 300 km above the surface, Galileo will provide detailed observations of the Earth and of the north polar region of the Moon. Infrared spectroscopy with the Galileo NIMS instrument will be most important observations. In addition, eight days after the closest approach, the Moon and Earth will be simultaneously in the field of view of probe's cameras so a "movie" could be made of the Moon passing in front of the Earth. On the remaining Earth-to-Jupiter trajectory, Galileo has an option to encounter the 30-km asteroid Ida in August 1993, with a decision on the option to be made in late 1992. A visit to Ida will cost about 35 kg of propellant that would otherwise be available for contingency use such as an extended Jupiter mission.

NASA's next planed planetary mission, the Mars Observer, is scheduled for launch in September 1992. It will go into orbit around Mars and provide detailed, planetary-scale, long-term observations of the planet. This will lay the groundwork for the next United States Mars mission, the Mars Network, which will consist of small measurement stations at different places on the planet's surface.

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Appendix

LIST OF SCIENTIFIC AND TECHNICAL PRESENTATIONS

I. SPECIAL SESSION TO CELEBRATE INTERNATIONAL SPACE YEAR ORGANIZED BY COSPAR AND IAF

Panel discussion on "Space and the Global Change Programme"

Moderated by Prof. John Carver, Chairman of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space.

Participants:
Mr. Jean-Marie Luton, Director-General of the European Space Agency;
Mr. Marcio Nogueira Barbosa, Director-General of the Brazilian Institute for Space Research;
Mr. Yoshihiro Ishizawa, Executive Director of the National Aerospace Development Agency of Japan;
Mr. John D. Schumacher, Deputy Associate Administrator for Policy Coordination and International Relations of the United States National Aeronautics and Space Administration;
Dr. M. G. Chandrasekhar, Scientific Secretary of the Indian Space Research Organization;
Mr. Jean-Daniel Levi, Director-General of the Centre National d'Etudes Spatiales of France.

Symposium on Space Technology and the Earth's Environment

Co-chaired by Prof. G. Ohring, Chairman of the COSPAR Commission on Space Studies of the Earth's Surface, Meteorology and Climate, and by Mr. Dale Fester, Vice President of IAF.

"Is the Earth Warming?," Dr. Thomas R. Karl, Chief, Global Climate Laboratory, National Oceanic and Atmospheric Administration, United States;

"Monitoring of Environmental Disasters from Weather Satellites," Mr. Luo Jibin, Director, Satellite Meteorological Centre, China;

"Novel Contributions by ERS-1 and SPOT to World Environmental and Climatological Issues," Guy Duchossois, ESA ERS-1 Mission Manager;

"The ISY World Forest Watch: Implications for Developing Countries," Dr. Roberto Pereira da Cunha, Brazilian National Institute for Space Research.

II. OTHER SCIENTIFIC AND TECHNICAL PRESENTATIONS

"Alternatives to the geostationary orbit," Prof. Nejat Ince, President of the Turkish Space Committee;

"International Microgravity Laboratory Mission - STS-42," astronauts Dr. Norman Thagard (United States), Dr. Roberta Bondar (Canada), Dr. Ulf Merbold (ESA);

"Remote Sensing Technology used in Hydrology," Dr. Thomas Caroll, Director of the National Hydrology Remote Sensing Center, Office of Hydrology, United States National Weather Service;

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"Remote Sensing for Sustainable Village Development in India," Dr. M. G. Chandrasekhar, Scientific Secretary of the Indian Space Research Organization;

"The Global Change Encyclopedia," Ms. M. C. Durand, Canadian Space Agency;

"Life Sciences and Space Medicine," Dr. Arnauld Nicogossian, United States National Aeronautics and Space Administration (NASA);

"Space Exploration of the Solar System," Dr. Carl Pilcher, Chief, Advanced Study Branch, Solar System Exploration Division, NASA;

"Mission to the Universe," Dr. Jeffrey Bennett, Assistant for Education, Astrophysics Division, NASA;

"Space Debris," Dr. M. G. Chandrasekhar, Scientific Secretary of the Indian Space Research Organization;

"United States Space Nuclear-Power Programme," Mr. Robert Lange, Office of Special Applications, Department of Energy, United States.